Low Cost Coherent Doppler Lidar Data Acquisition and Processing

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ABSTRACT

The work described in this paper details the development of a low-cost, short-development time data acquisition and processing system for a coherent Doppler lidar. This was done using common laboratory equipment and a small software investment. This system provides near real-time wind profile measurements. Coding flexibility created a very useful test bed for new techniques.

1. Introduction

Data acquisition and processing systems can consume a large share of a lidar systems budget. Also, their complexity demands equally complex coding, which requires a considerable investment in man-hours for software development to make it all work. This was the case in the development of Validar[1]. A complex, real-time system was planned and underdevelopment, but a system was needed to further the development of the Validar in the meantime. As a result, a near real-time system was developed using equipment on hand and National Instruments LabVIEW software. A diagram of this system is shown in figure 1. This system uses a Tektronix TDS 784D digital oscilloscope as a high-speed digitizer and transfers the data to the computer via the GPIB interface. LabVIEW is an excellent choice for the development of software for anyone interested in an easy to use and flexible programming language. It is a graphical programming language that frees the developer from the typical syntax concerns of text-based languages. The program is fully compatible with and functions under the Windows operating system, allowing data retrieval onto portable media that can be processed on any home/office PC.[2] Also, major instrument manufacturers recognize its value and have drivers written for their instruments. This results in a great savings in development time because the much of the tedious work of creating drivers and user interfaces is already done.

2. Data Acquisition System

The system that was developed for Validar functions as follows: first the user adjusts the oscilloscope voltage and time base settings to acquire the atmospheric return. This is typically 75,000 points acquired at a rate of 1Gs/s. Then the user sets the acquisition and processing parameters with the software's graphic user interface, shown in figure 2. With all parameters set the program communicates with the DFM, Inc. lidar scanner using the RS-232 interface to update its position. Next, the program works with the digital oscilloscope and acquires the number of lidar returns that the user has requested. Due to the data transfer rate of the GPIB interface data is acquired at a laser pulse repetition rate of 0.5 Hz. For wind profile measurements, the lidar scanner position is updated and the lidar returns are again acquired. The acquisition of a full, three directional wind profile of 10 laser pulses in each direction is accomplished in less than 1.5 minutes.

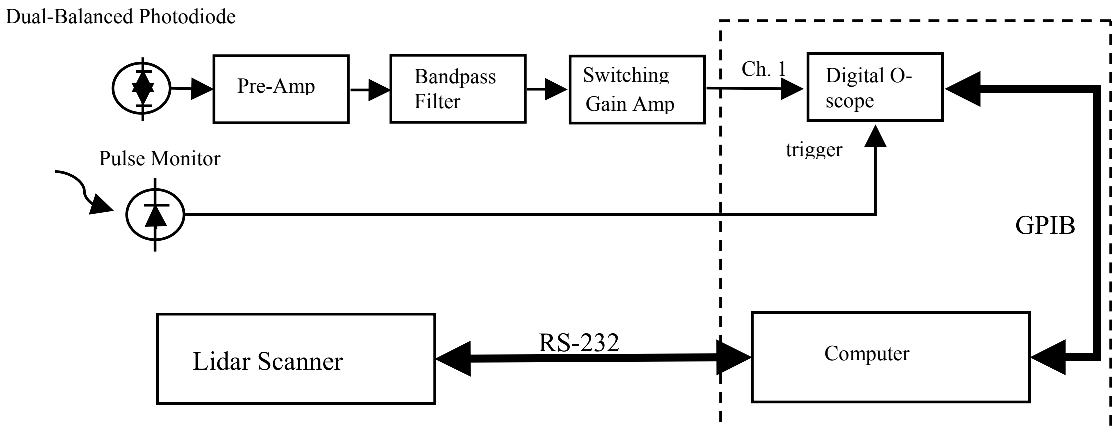

Figure 1: System Diagram

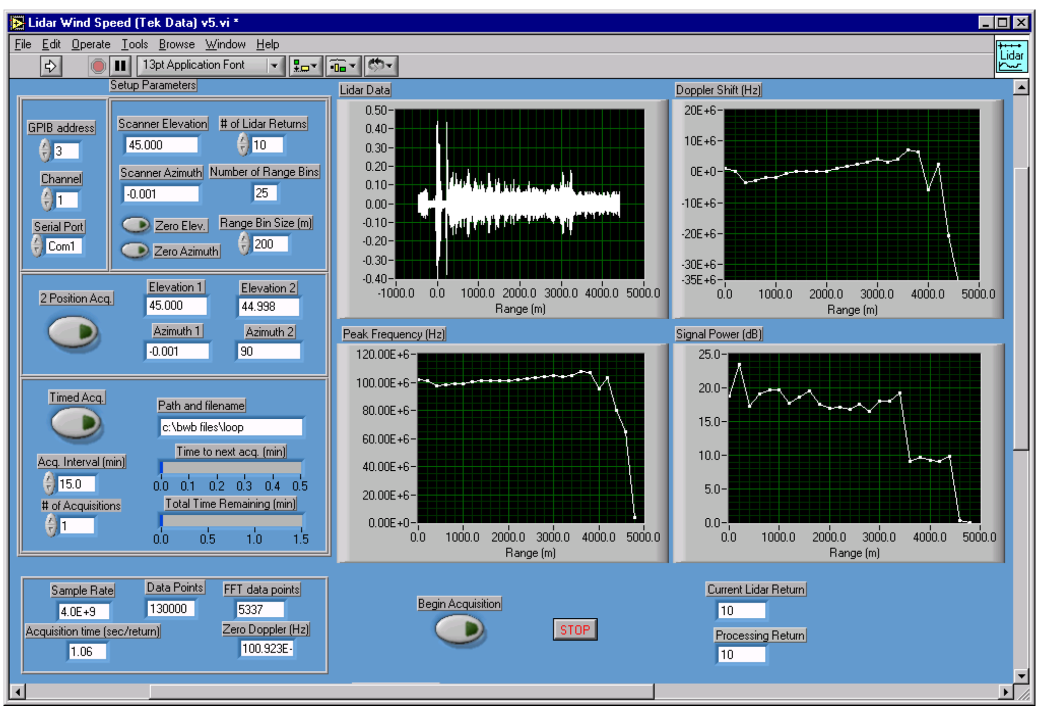

Figure 2: Acquisition and Processing User Interface

With all of the positions acquired, the data is processed. Before the FFT spectra of the returns collected at each scanner position can be averaged. Any jitter in the intermediate frequency of the laser must be monitored and corrected for jitter. The Validar laser has a typical shot-to-shot frequency jitter of 1-5MHz. This correction is vital because at the laser wavelength of 2µm a 1MHz Doppler shift equates to 1m/s in wind speed. This correction is done by measuring the frequency of the backscattered signal from the optics in the telescope in the first portions of the lidar return. The frequency of the first pulse is set as the standard and all successive pulses are compared to it. If the frequency has jittered then the spectrum of the return is shifted to correct the jitter. With intermediate frequency jitter compensation complete the spectra of the atmosphere returns are averaged. The resulting spectrum is partitioned into range bins. The size of the range bins are carefully chosen to insure a minimal spectral resolution of 500kHz, this equates to a wind speed resolution of 0.5m/s. The peak frequency and signal power in each range bin is measured and plotted.

3. Wind Profile Measurements

Because lidar is a line-of-sight measurement it is necessary to acquire two orthogonal lidar returns to determine the true wind speed and direction. The vector sum of these returns yields the wind profile assuming zero vertical wind speed. Figure 3, shows two orthogonal returns and their vector sum with wind speed and direction. The assumption of zero vertical wind speed is not completely valid. In addition to acquiring the two wind profile vectors, a vertical vector is also acquired. A time trend of vertical wind speed that was acquired over a 4.5 hour time period shows vertical wind speed in the range of ±2m/s. This can result in small errors in the wind profile data. While it is possible to add the vertical wind speed measurements to the vector sum this would require the assumption that the vertical wind is uniform over the full range of the measurement (up to 5km).

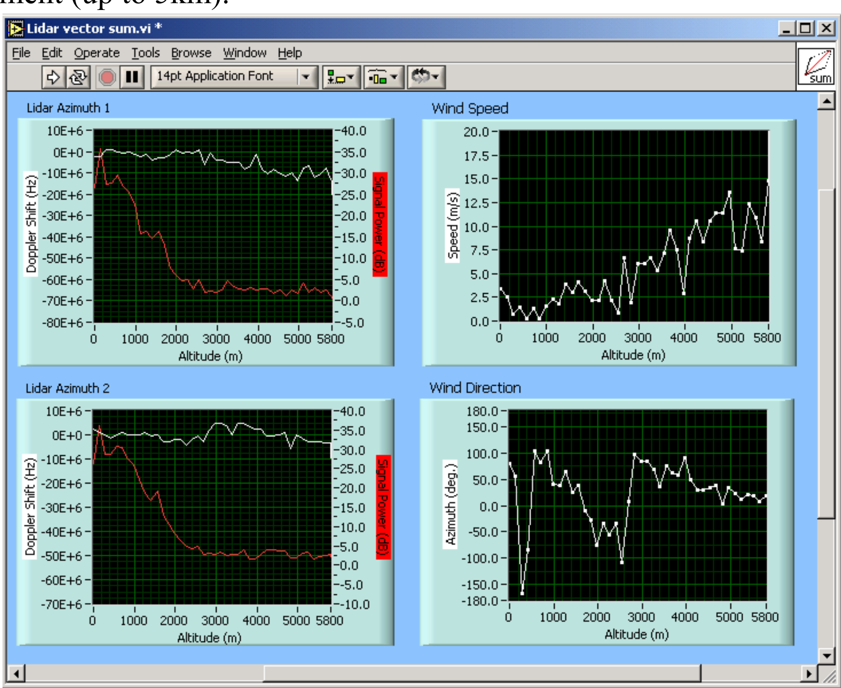

Figure 3: Vector Sum of Orthogonal Returns

This data acquisition and processing system is also capable of acquiring data automatically at timed intervals. In a timed acquisition mode the system positions the lidar scanner, acquires lidar returns, processes and saves data, and repeats at specified intervals. This feature produces wind profile data that is displayed in a time lapsed loop of displays of wind speed vs. altitude and wind direction vs. altitude as shown in figure 4.

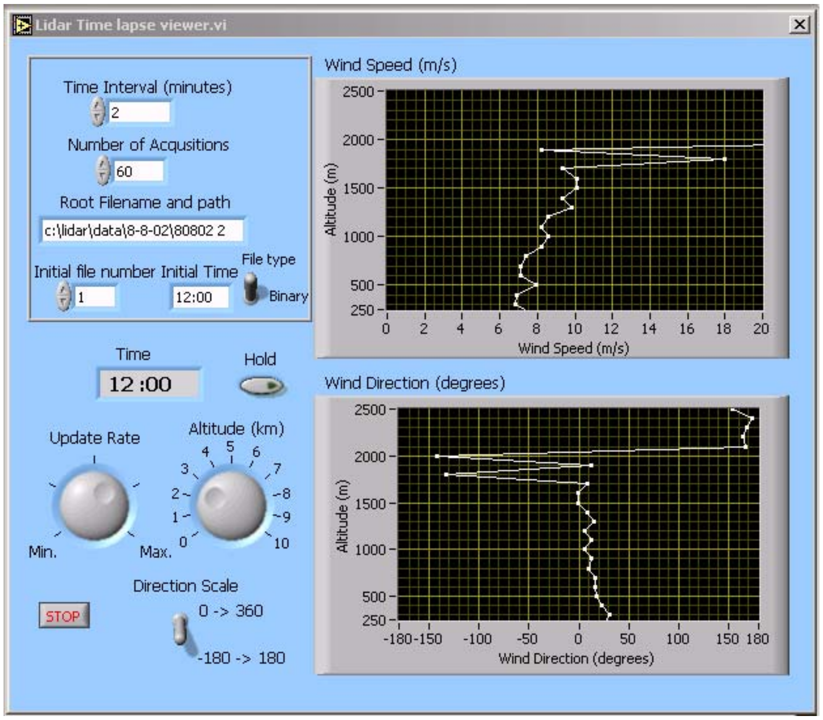

Figure 4: Wind Profile Time Lapse Loop

4. Conclusions

This system is very effective at acquiring near real-time wind profile data. Due to the user friendliness of the LabVIEW graphical programming language this system was developed and operational in only 3 months. Because it utilized existing laboratory equipment the only equipment costs involved in the implementation of this system were the purchase of a GPIB interface card and the LabVIEW software for a total cost of approximately $2500. Finally, the code of the real-time system is far too complex to allow for the easy adaptation as a test bed for new ideas. The versatility of the LabVIEW programming environment makes this system an excellent test bed for new frequency estimation and data processing techniques.

5. References

1. G.J. Koch, M. Petros, B.W. Barnes, J.Y. Beyon, F. Amzajerdian, J. Yu, M.J. Kavaya, and U.N. Singh "Validar: A Testbed for Advanced 2-μm Coherent Doppler Wind Lidar," 12th Coherent Laser Radar Conference, Bar Harbor, ME (2003)
2. M.R. Huff, "A LabVIEW Based Wind Tunnel Data Acquisition System" M.S. Thesis, Naval Postgraduate School (1998).